

***Dicymolomia julianalis* (Lepidoptera: Pyralidae) as an
Endoparasite of the Bagworm, *Thyridopteryx ephemeraeformis*
(Psychidae): Its Relation to Host, Life
History and Gonad Development**

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Abstract.—In central Oklahoma, larval *Dicymolomia julianalis* Walker (Lepidoptera: Pyralidae) attacks the eggs, larvae and pupae of the common bagworm, *Thyridopteryx ephemeraeformis* (Lepidoptera: Psychidae) at the rate of 21%, 7% and 12% respectively. Beside preying on the bagworm eggs, it burrows into the body of a living larva or pupa and lives on the host's inner organs for several months until pupation. *Dicymolomia julianalis*, therefore, is an endoparasite, as well as an egg predator of the bagworm. Twenty percent of those that had parasitized the immature stages of the host became adults, as opposed to 80% of those that had preyed on the eggs.

The microscopic eggs of *D. julianalis* aestivate during summer months to hatch in August–September, synchronous with the availability of host eggs and pupae. A larva consumes $\frac{2}{3}$ to $\frac{3}{4}$ of the eggs in a pupal case, leaving the rest to hatch in spring. There is as yet no fixed pupation behavior. Of the total of 1912 bags containing live eggs, larvae and pupae, 15% were affected by this organism, as opposed to 6% by several different species of hymenopterans.

The development of gonads in both sexes is described.

Like many other pyralid larvae, the larva of *D. julianalis* had been known as a general detritus feeder (Munroe, 1972). However, Gahan (1909), McCreary (1930), Balduf (1937), and Barrows (1974), after finding *julianalis* larvae in the fresh egg mass of the bagworm, described them as egg predators. Only the last mentioned author was not certain whether the eggs were eaten or crushed by the burrowing activity of the pyralid larvae. In 1981, I repeated these findings, confirming this species as an egg predator, but at the same time, I discovered “another” lepidopterous larvae, similar to those of *julianalis* but different in color and size, parasitizing the larvae and pupae of the same bagworm. I isolated these larvae for observation, but none of them pupated; all died after a few months. Toward the end of 1982, I found a larger number of the same larvae, and since there seemed little morphological difference between these and the *julianalis* larvae, I fed them with bagworm eggs after the larvae had reached the last instar within their original hosts. The emerged adults were identified as those of *Dicymolomia julianalis*, thus establishing a new status of this species as an endoparasite of *Thyridopteryx ephemeraeformis*.

Records of lepidopterans endoparasitic upon other lepidopterans are almost unheard of. This paper examines the host-parasite relationship between these two

Table 1. Details of the bagworm bags examined.

No. of empty male bags (due to emergence)	1284
No. of empty female bags (causes unknown)	17
No. of bags eaten by birds:	
♂ bags	332
♀ bags	196
No. of bags with unfertilized females	49
No. of bags with dead larvae (causes unknown)*	87
No. of bags with dead pupae (causes unknown)*	31
No. of bags with fresh eggs	887
No. of bags with living larvae	410
No. of bags with living pupae	615
Total no. of bags examined:	3908

* In these two groups, the bodies of larvae and pupae were whole; they contained no recognizable parasites or bore any holes on the body wall.

species of butterflies, as well as the ecological, biological, and anatomical aspects of *Dicymolomia julianalis*. I hope that this work may contribute more details to the existing knowledge of this microlepidoptera.

MATERIALS AND METHODS

Bagworms were collected once every week from juniper and arborvitae trees at 10 different sites in Norman from August 1981 to April 1983. The collected bags were then cut open and examined for parasites; those infested were individually isolated in small glass jars until emergence of the parasites. Exceptions were those collected in August and September, all of which were kept isolated in this way, because the pyralid larvae at eclosion were too small to be detected among the bagworm eggs, or in pupae and larvae. The total number of the bags thus examined was 3908 (Table 1). Aside from these, from May to August, some 400 immature larvae of various instars were also examined for possible parasites. Similarly, in order to find out the identity of those lepidopteran larvae found in bagworm larvae and pupae, the total of 80 such individuals (40 in larvae, 40 in pupae) were divided equally into 4 groups as shown below:

Group 1. — 20 *julianalis* larvae left alone with their original larval hosts (control).

Group 2. — 20 *julianalis* larvae singly transferred to bags containing fresh bagworm eggs, after reaching the final instar within the original larval hosts.

Group 3. — 20 *julianalis* larvae left alone with their original pupal hosts (control).

Group 4. — 20 *julianalis* larvae singly transferred to bags containing fresh bagworm eggs, after reaching the final instar within the original pupal hosts.

Emerged adults were released into a cage (30 × 30 × 30 cm) provided with a bagworm-infested arborvitae branch for mating and oviposition.

To study the development of gonads, 1–3 day old adults of both sexes were dissected under the stereoscopic microscope. In males: testes, vasa deferentia, vesicula seminales and accessory glands; in females, ovaries, oviduct, bursa copulatrix, spermatophores and receptaculum seminis, were crushed lightly between a slide and a cover glass and examined under the compound microscope.

Table 2. The frequency of *D. julianalis* larvae found in different stages of *T. ephemeraeformis* and the percentage that became adults.

	No. of bags containing live			Total
	Eggs	Larvae	Pupae	
	887	410	615	1912
No. of bags infested by <i>D.j.</i> larvae	189	30 (9 ♂, 21 ♀)	76 (38 ♂, 38 ♀)	295 (47 ♂, 248 ♀)
Infestation of <i>D.j.</i> larvae against original no. (%)	21.3	7.3	12.4	15.4
% of <i>D.j.</i> larvae that became adults	80	5	15	100

RESULTS

Host

Larval *Dicymolomia julianalis* attacks all stages except adult of the common bagworm, *Thyridopteryx ephemeraeformis* in various degrees depending on the sexes and the developmental stages of the host (Table 2).

The relationship between each stage of the host and the parasite will be examined separately.

(1) *Host-eggs*.—A batch of bagworm eggs is contained in a female pupal case and is protected by a “plug” consisting of shed female body hairs. *A. julianalis* larva enters an egg-filled pupal case from the opening made by the female host, and begins feeding on the eggs. As it grows, the larva molds the soft, yellow-brown hairs of the plug just mentioned into a tube which perhaps protects its occupant against cold during the winter months (Fig. 1A). As the larva continues feeding, sticking its head out of the tube after the manner of the bagworm larva, some more hairs are added to lengthen the tube which, at its final stage, may occupy almost the entire length of the pupal case. By the time the larva is fully grown, $\frac{2}{3}$ to $\frac{3}{4}$ of the eggs in the bag have been consumed, leaving the rest unmolested; therefore, a pyralid-infested bag still yields bagworm larvae in spring. In this connection, mention should be made that Gahan (1909) and McCreary (1930) stated that bagworm eggs were completely consumed, while according to Balduf (1937), the eggs were “reduced to various extent.” In my observations, no bags occupied by a single *julianalis* larva were found empty. Normally one bag contains only one *julianalis*, but in about 4% of the specimens examined, two individuals shared a bag. In such cases, either both larvae starved to death, or the one which had pupated first was devoured by the second, still in its feeding stage. The pyralid larvae that had fed on the host eggs were white and fat, in comparison to yellow and thin larvae that had parasitized the immature stages of the bagworm. Eighty percent of the egg feeders successfully became adults.

(2) *Host-larva*.—Only the last instar host-larvae are attacked, since in August–September, when the parasite eggs hatch, the great majority of the hosts have either pupated or oviposited leaving only a small number of last instar larvae. A newly eclosed *Dicymolomia julianalis* larva penetrates the body wall of the host

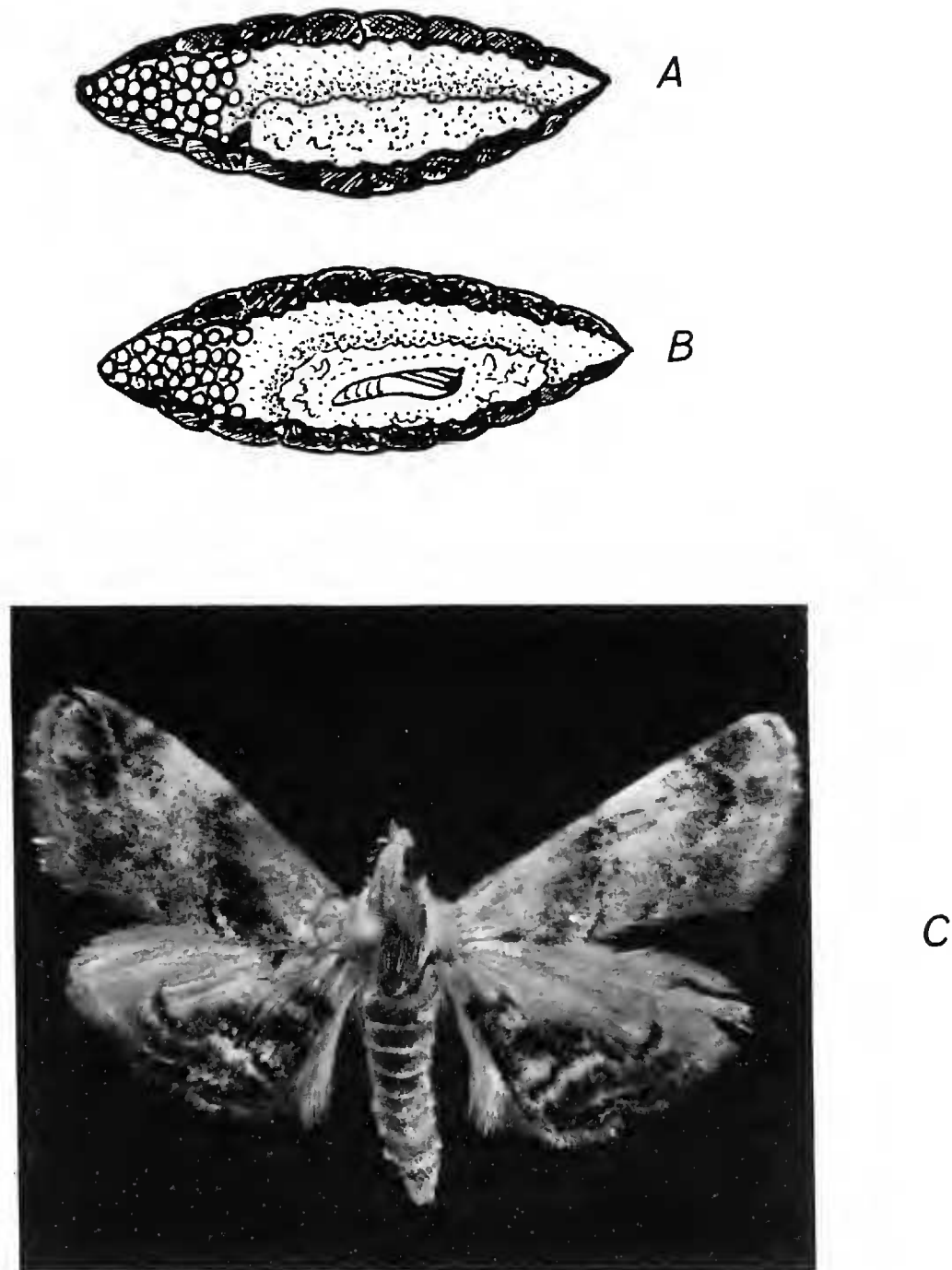


Figure 1. A. *Dicymolomia julianalis* larva in tube made of host body hair, feeding on bagworm eggs. B. Pupa in sealed larval tube. Note the remaining host eggs. C. Adult female (wing span: 10 mm).

and consumes all the fat and inner organs in 5–6 months, depending on the size of the host (female bagworm larvae are larger than male larvae; also, the well nourished are considerably larger than the undernourished). The parasite may then pupate inside the empty larval cuticle of the host without spinning a cocoon, or chews an irregular hole through the host's body wall, emerges, constructs a silken cocoon and pupates in the bag. Only 5% of those which had parasitized bagworm larvae became adults. The rest, upon emerging from the hosts, spun flimsy "tents" inside the bags and remained there as such for as long as 4 months. These larvae progressively became thinner and weaker, turned brownish and eventually died, but if such larvae were transferred to bags containing fresh eggs soon after they reached the last instar, then 70% reached adulthood as opposed to 5% in the control (see Methods).

(3) *Host-pupa*. — The manner of host-pupa parasitization and pupation are similar to those just described in the host-larva. Fifteen percent of this group succeeded

in becoming adults (6.5% emerged from male pupae, 8.5% from female pupae), as opposed to 80% in the egg-feeding group. The reason why more females than males are attacked is that while winged males vacate their bags immediately after emergence, vermiform females remain in them until oviposition is completed. Some of the parasites which had developed into adults on this diet consumed not only the inner organs, but also the entire exoskeleton of the host. At least one even fed on its own excretory pellets so that the interior of the host bag was literally empty except for the pupal case of the emerged parasite. If the pyralid larvae which would not pupate after consuming their pupal hosts were given bagworm eggs, then they continued development, pupated and 90% became adults as compared to 15% in control (see Methods). This fact indicates that the arrested development of the parasites was due mainly to a nutritional deficiency.

Population

The occurrence of *Dicymolomia julianalis* populations was restricted largely to 3 of the 10 collection sites. In general, bagworm-infested juniper and arborvitae trees in isolated, undisturbed fields had far larger pyralid population concentration than those near human dwellings or roads. In favorable localities, the proportion of the bagworms affected by this organism ranged from 13 to 20%.

Pyralid larval populations appear first during August–September when bagworm eggs become available, and reach a maximum from October to the following April during which host eggs hibernate. The minimum period is from late May to late July when only immature host-larvae are present in the wild. Of the total of 1912 bags containing live eggs, larvae and pupae, 15% were affected by this parasite (Table 2) as opposed to 6% by other endoparasites consisting of 3 species of ichneumonids and 2 species of chalcids.

Life History

Eggs.—Eggs are microscopic, measuring 0.5 mm long and 0.3 mm wide at center. They are yellowish-white and flatten soon after deposition, clinging to the substrate. These eggs aestivate from April–May to August–September, a period of some 4 months.

Larvae.—Newly eclosed larvae are only about 1 mm long. No morphological adaptation to the parasitic life is apparent: all 3 pairs of thoracic, as well as 5 pairs of abdominal legs with characteristic hooks are present. Larvae grow to 10 mm long in 5–6 months after several (5–6) molts.

Pupae.—The larval tube made of host hairs mentioned earlier is open on both ends. Later, however, a last-instar larva may close the openings and convert it into a cocoon in which to pupate (Fig. 1B). Some 80% of the pupae of *julianalis* found among host-eggs were inside such cocoons. As to the remaining 20%, some emerged from the host-puparia and constructed their own silken cocoons within their host-bags, while a few made no cocoons at all, but lay “naked” under the host-puparia or in some other concealed niches in the bags. Thus the pattern of pupation varies. Pupae are able to move their abdominal segments vigorously when disturbed. Pupal period lasts from 14–26, an average of 21 days.

Adults (Fig. 1C).—Adult emergence occurred as follows: 3% in February, 15% in March, 50% in April, and 32% in May (sample size: 295). Sixty percent of the parasites became adults before the eclosion of the host larvae, while 40% did so

after eclosion. Of the latter group, 20% emerged successfully; the rest were partly or completely eaten as pupae by the eclosed bagworm larvae. Most of these victims were without cocoons; some had hair-cocoons which were penetrated by the host-larvae. Newly eclosed bagworm larvae are normally vegetarians, but turn facultatively carnivorous whenever opportunities arise; they also devoured other dead insects including the adults of their own species when these were experimentally provided.

Adults are sexually mature at emergence. The sex ratio was 44% males and 56% females; this ratio coincided with that of the bagworm bags collected at random from the field. Fifty-five percent of the caged females mated soon after emergence; this figure could have been higher, if the first nine adults that emerged had included males among them. Eggs were laid on the surfaces of the bags and wooden frames of the cages. Adult life span did not exceed 2–3 days in both sexes.

Development of Gonads

Male.—The structure of the male reproductive system is shown in Figure 2. It is almost identical with that of *Maruca testulalis* (Kaufmann, 1983); the only morphological difference is that in *julianalis*, the vas deferens consists of 3 bulbous parts instead of 1. Testes are comprised mainly of encysted spermatozoa and those that have just been freed from the cysts, the individual spermatozoa of which, therefore, are still tightly held together at this stage (Fig. 2Bb). The spermatozoa of this species (Fig. 2Ba) are 2–3 times the length of those of *Maruca testulalis*. Free spermatozoa develop only in the third bulb (Fig. 2A) of the vas deferens. This bulb also contains encysted forms beside free spermatozoa (Fig. 2Bc) both of which are then transferred to the vesiculum seminis. Due to the secretion received from the paired accessory glands, vesicula seminales as well as the third bulbs of the vasa deferentia are prominently white in color. It is probable that without this accessory gland secretion, the free stage of the spermatozoa does not develop. The unpaired accessory gland contains an opaque material in the upper part, and milky white, granular substance in the lower part, the diameter of which is twice as large as that of the upper part. Both of these secretions together with spermatozoa form the spermatophore in females.

The development of free spermatozoa occurs within the first 24 hours after emergence, in comparison to 4–5 days in *Maruca testulalis* (Kaufmann, 1983). This is probably because the adult life span of this species is limited to 2–3 days, while that of *testulalis* covers 12 days.

Female.—The female reproductive system of *julianalis* differs from that of *testulalis* in the following features, namely: (1) ovarioles have no terminal filaments, (2) seminal duct arises directly from bursa copulatrix, (3) bursal gland lies immediately below bursa copulatrix to which it is directly connected without any duct, and (4) both bursa copulatrix and bursal gland are enveloped in a common, thin, transparent outer sac (Fig. 3A).

Ovaries contain mature ova at emergence; each of the 4 ovarioles contains about 25 eggs and therefore, the total number of eggs per female is $2 \times (25 \times 4) = 200$. However, the number of mature eggs at any one time is about 80.

The spermatophore of this insect consists of a round sperm sac and a tube, resembling the early stage of a tadpole (Fig. 3C1). When fresh, this entire structure is pearly white. A single spermatophore occupies the entire cavity of the bursa

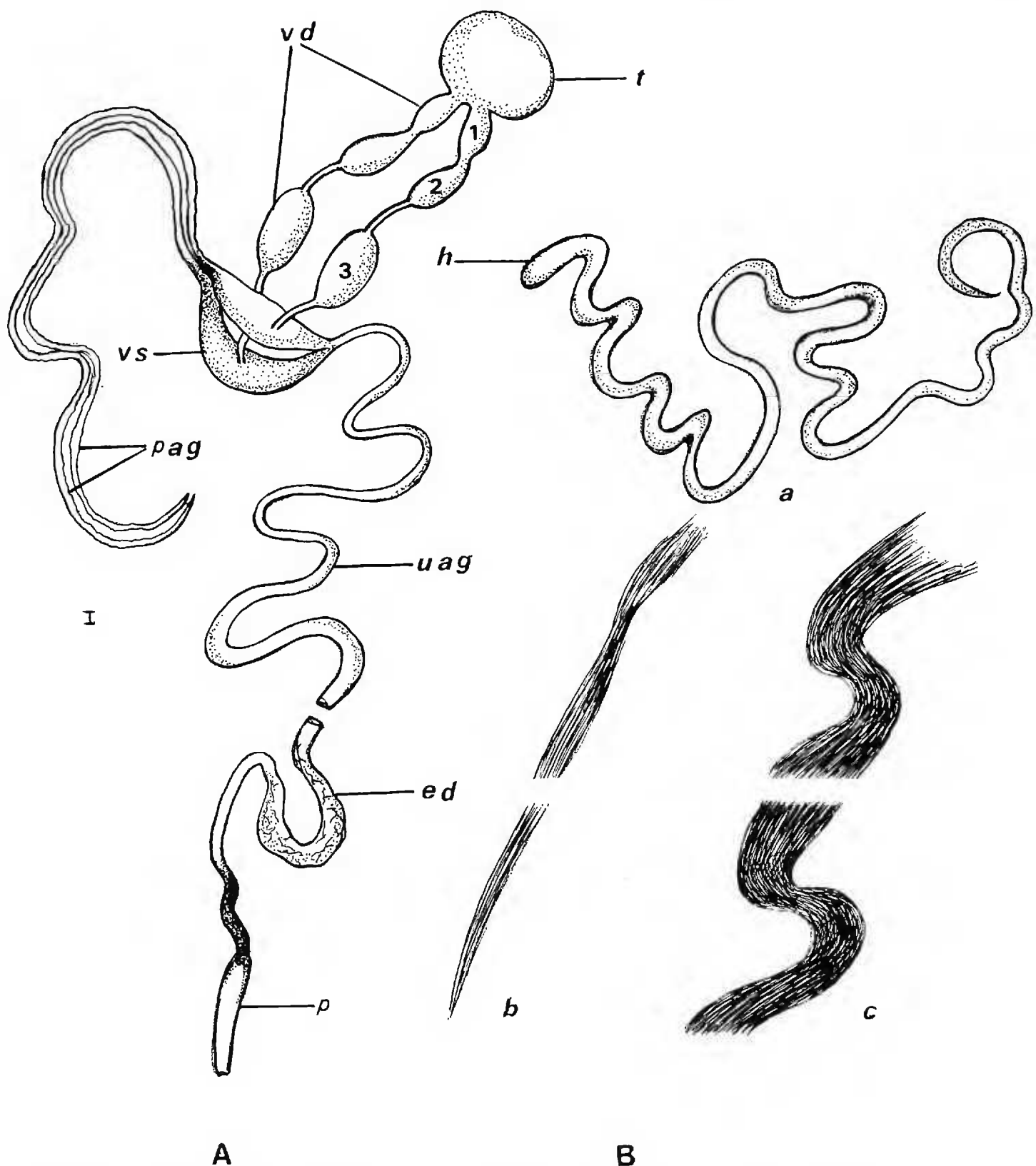


Figure 2. Male reproductive system. A. Entire system. t: testes, vd: vas deferens, vs: vesiculum seminis, pag: paired accessory glands, uag: unpaired accessory gland, ed: ejaculatory duct, p: penis. B. a: testicular cyst, h: head, b: spermatozoa immediately after being freed from cyst, c: free spermatozoa.

copulatrix. Unlike in *Maruca testulalis*, there is only one chitinous rod lying on the side of the seminal duct of the bursa (Fig. 3C3). When the muscular wall of the bursa contracts, this stout rod presumably squeezes the spermatophore between it and the opposite wall of the bursa, and in so doing, the spermatozoa are flushed out through the seminal duct and reach the receptacula seminis via seminal canal (Fig. 3B). An empty spermatophore quickly shrinks and 3 days after emergence, only a small residual body is seen in the seminal duct adjacent to the bursa (Fig. 3C3). As in *testulalis*, during the process of fertilization at vestibulum, some

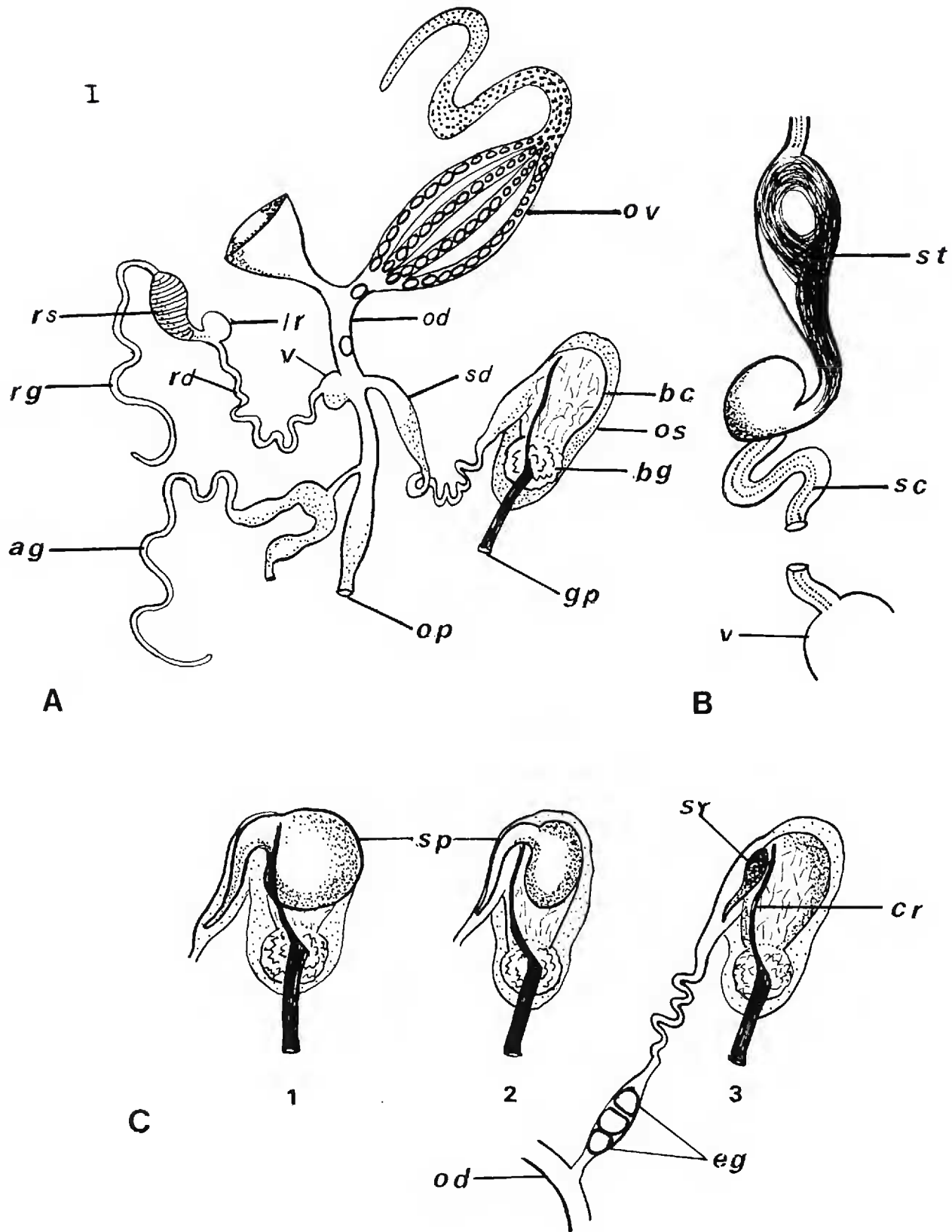


Figure 3. Female reproductive system. A. Entire system. ov: ovary with eggs, od: oviduct, sd: seminal duct, bc: bursa copulatrix, os: outer sac, bg: bursal gland, gp: gonopore, v: vestibulum, rs: receptaculum seminis, lr: lagina receptaculi, rd: receptacular duct, rg: receptacular gland, ag: accessory gland, op: ovipore. B. Receptacular system. st: spermatozoa, sc: seminal canal. C. Bursa copulatrix with spermatophore. sp: spermatophore, sr: residue of spermatophore, cr: chitinous rod, eg: stray eggs in seminal duct.

of the descending eggs get caught in the seminal duct; one such stray egg is common, but as many as 3 have been observed (Fig. 3C3).

DISCUSSION

Where bagworms are locally abundant, especially in quiet, undisturbed fields, the larvae of *D. julianalis* are also concentrated. From late August to September,

when *julianalis* eggs hatch, the bagworm populations in central Oklahoma roughly consist of 65% eggs, 25% pupae, and 10% larvae. Consequently, chances are that the largest number of the newly eclosed *julianalis* larvae find bags containing eggs followed by those with pupae, while those that encounter bags occupied by larvae will be the smallest numerically. Since the eclosion of this pyralid larvae is synchronous with the availability of bagworm eggs, feeding of the eggs by *julianalis* larvae is no more opportunistic than finding the bags filled with eggs. Moreover, *D. julianalis* larvae show an evolutionary trend of adaptation for egg predation such as the construction of protective tubes around their body, and the conservation of a part of the host eggs which, no doubt, contributes to the survival not only of the host species, but also of the predator itself. Such predation is clearly very different from that of other carnivorous butterfly larvae including those of *Spalgis epius* (Lycaenidae) which prey on coccids, or several other lycaenid larvae of similar habits (Clark, 1926).

As to those *julianalis* larvae which happen to enter the bags containing living larvae or pupae, it is a form of parasitism, since they live within the living hosts at the expense of the hosts' body fat and inner organs for their sustenance for the period of some 6 months—the definition of parasitism given by Brues (1946).

Many years ago, I worked on the biology of several different species of Tenebrionidae in Israel. Up to that time, these beetles were thought to live mainly on debris such as dry and decaying plant materials and excrement (Bodenheimer, 1935). My breeding experiments showed, however, that those larvae which fed on dead or living insects and other animal food developed faster with only small mortality than those which fed on both insects and debris. The larvae which were given only debris never pupated, but remained as "permanent" larvae (Kaufmann, 1969). In nature, these tenebrionids feed on debris when there is no other choice, but when an opportunity arises, they eagerly eat other animals. Perhaps the same can be said about *D. julianalis*. Gahan (1909) was informed that larval *D. julianalis* had been known as a scavenger of the common *Typha*, or cat tail. Munroe (1972) describes this species as a detritivore like many other pyralid larvae. The crucial question is: can they develop on detritus only? My own figures show that only 5% of *julianalis* larvae which parasitized bagworm larvae became adults. Yet, these hosts were alive, not dead, at the time they were attacked. If *julianalis* larvae fed exclusively on detritus, their chances of reaching adulthood could be very slim. At any rate, the feeding of bagworm eggs must have been going on for quite some time—long enough to develop the characteristic feeding behavior I have described. Be that as it may, whether the egg-, larvae-, and pupae-feeding of this pyralid should be regarded as a form of predation, parasitism, or both, depends mainly on the opinion of the entomologist. In nature, especially among insects, clear-cut distinctions between the two simply do not exist because of an intergrading.

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